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Distribution Patterns of DDT Residues in the Sierra Nevada Mountains

Lawrence Cory,¹ Per Fjeld,¹ and William Serat²

ABSTRACT

Frogs from throughout the Sierra Nevada Mountains in California were examined for pesticide residues. The commonest substance found was p,p'DDE, a metabolite of p,p'-DDT, and its occurrence was regarded as evidence of environmental contamination with DDT residues. Contamination of the range was found to be general throughout, even at altitudes to 12,000 feet above sea level. General patterns of distribution showed that concentrations were highest in the central to southern areas and declined somewhat to the north. Contamination was heavier on the western slope of the mountains than across their crest on the east face. The presence of the residues is ascribed to wind-borne drift of aerosol DDT released in crop-dusting in the central valley of California. Notably high concentrations in a limited area in the Yosemite National Park to Sonora Pass region are considered to be locally persistent residues of forest sprayings with DDT made in this area in 1953 and 1956.

Introduction

Examination of a map of the State of California (Fig. 1) shows the prominence of the central valley, formally designated the Sacramento Valley North of the latitude of San Francisco Bay and the San Joaquin Valley to the south. Located to the east of this valley and extending approximately parallel to it in a north-south direction lies the Sierra Nevada Mountain Range. This range is over 300 miles in length and averages about 40 miles in width. The highest altitude in the continental United States, over 14,500 feet at Mt. Whitney, occurs near its southern end, and the range includes many areas rising to well over 13,000 feet. The several

rivers draining various areas of the northern part of the valley converge to a common trunk in the Sacramento River, just as those draining the southern valley regions join to form the San Joaquin River trunk. These two river systems merge in an extensive delta area, through which their common effluent is discharged into San Francisco Bay.

The topographic relationships of these regions to each other and to the Pacific Ocean which lies west of them have important meteorological consequences. For one thing, prevailing winds blowing across the State are from the ocean, so that they sweep from west to east across the central valley and against the Sierra Nevada. In crossing the range, the rising air masses release much of their moisture as precipitation on the western face of the mountains. The amount of precipitation drops sharply to the east of the Sierra Nevada crest, which marks the western boundary of the great desert areas of the Western United States. These topographic and meteorological features have important implications with respect to the distribution patterns of DDT* residues we are finding.

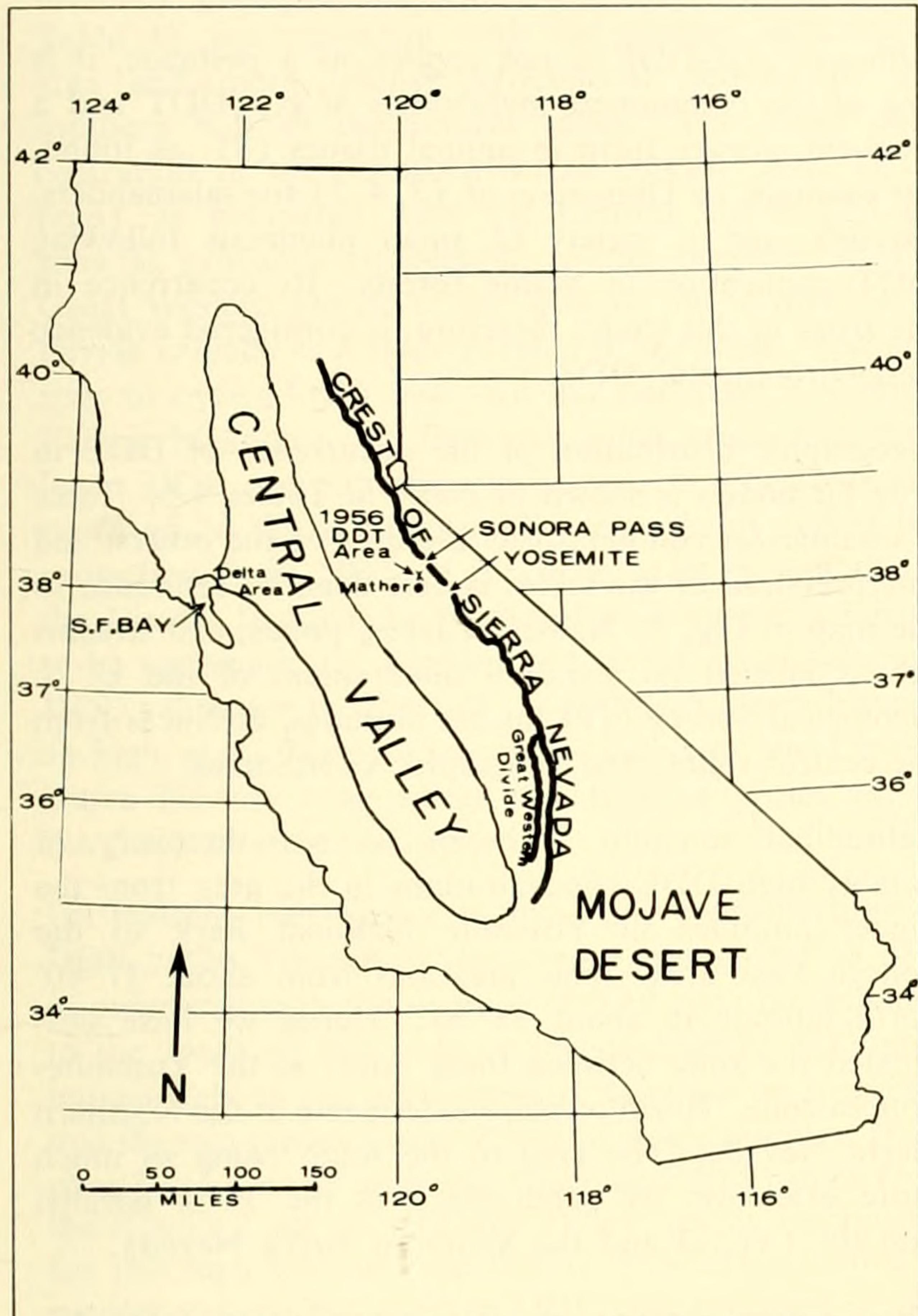
The central valley of California is agriculturally one of the most intensely cultivated areas on the earth. In this agricultural activity enormous amounts of pesticides are employed, including a high percentage of DDT. Exactly how much of this material has been used is impossible to determine, but conservative estimates in the mid-1950's indicated that about 20% of all DDT used in the United States was employed in California agriculture. (Robert Rawlins, *California*

¹ Biology Department, St. Mary's College, Calif. 94575.

² California State Department of Public Health, Berkeley, Calif. and Biology Department, St. Mary's College, Calif.

* Term designating *o,p'* and *p,p'* isomers of 1,1,1-trichloro-2,2-bis-(*p*-chlorophenyl) ethane, as well as dehydrochlorination products, as *p,p'*-DDE.

FIGURE 1.—Map of the State of California showing relationship of the Sierra Nevada Mountain Range to the central valley



State Department of Agriculture, personal communication). Figures from U. S. Tariff Commission Reports quoted by Frost (7) and by Sodergren (9) indicate that the annual production and sale of DDT in the United States has increased steadily from 19,000 tons per year in 1946 to a maximum of 79,000 tons per year in 1962, with somewhat of a decline thereafter. Increasing export of the material is indicated by the 79% export fraction of the 69,000-ton U. S. production in 1968. Dobzhansky *et al.* (6) quote estimates of 3,243 tons and 3,168 tons of DDT used in California agriculture in the years 1951 and 1955, respectively, values that are consistent with the above figures. At the rate of use indicated by these estimates, the total amount of DDT applied to the central valley of California since its introduction into agricultural use in 1945 becomes an awesome figure.

Most of this material is applied in crop-dusting by airplane. It can be expected that much of this material in aerosol form would be carried eastward from the valley by the prevailing winds, and that much of this transported material would be deposited in the Sierra Nevada, either by direct fallout in local eddies in

canyons and glacial cirques or associated with the precipitation of moisture, in the manner indicated by Cohen and Pinkerton (1).

Field Methods

A search for DDT residues is being made in body tissues of frogs of the *Rana boylei* group (the "yellow-legged" frogs). Previous work (2) had shown the widespread distribution of these animals throughout the Sierra Nevada, especially in the broad band of lakes and ponds in glacial cirques alongside the main crest. Frogs being well along in the series of food chains represent a good indicator species for the assessment of pesticide base levels. In frogs, moreover, the fatty tissues are not widely scattered subdermally throughout the animals, but are concentrated in a discrete pair of fat bodies. It is this tissue that is analyzed.

Collections are made in the course of back-packing expeditions throughout the most remote areas in the mountains, and insofar as possible no use has been made of animals occurring near trans-montane highways or major trails, where random accidental local contamination might occur. Frogs are brought to the laboratory alive. They are killed by being quickly deep-frozen immersed in water, a condition in which they are kept until analyzed.

Analysis

Processing is a modification of the technique of Stanley and LeFavoure (10). Fat-body tissue is broken down into an emulsion in a commercial perchloric-acetic acid mixture (BFM Solution, G. F. Smith Chemical Company, Columbus, Ohio). For the small amount of tissue in a pair of fat bodies from the yellow-legged frogs (generally less than 1 gram), 1 ml to 3 ml of the acid mixture is sufficient. Upon standing for 24 hours, the tissue is broken down to an emulsion, and a layer of lipid is visible on the surface. This emulsion is shaken with 10 ml of pure hexane (Mallinckrodt, Nanograde) in a separatory funnel, and the hexane layer containing lipid-soluble materials is separated from the acid residue. The latter is re-extracted a second and a third time with 10-ml portions of hexane, and all three extractions are combined in a separatory funnel. To this combined extract are added 5 ml of analytical grade concentrated sulfuric acid, then 5 ml of analytical grade fuming sulfuric acid (20-23% SO₃). The funnel is quickly stoppered and shaken vigorously by hand for 2 minutes. This treatment destroys fats and many other substances but leaves intact many lipid-soluble components, including the DDT-related compounds. Upon standing, usually for 24 hours, a clear hexane layer separates from the acid phase. This hexane

phase, containing the DDT-related substances, is drawn off and concentrated by evaporation to a small volume, generally about 1 ml. This concentrated extract is retained in a stoppered, calibrated cylinder for examination by gas-liquid chromatography, and together with rinsing from the evaporation vessel, totals a few milliliters in volume.

In the examination of this final hexane extract by gas-liquid chromatography, a Wilkens Aerograph HY-FI Model 600 instrument was employed, under the following conditions:

Detector:	Electron capture, with 250 μ c tritium source
Carrier gas:	Nitrogen
Temperature:	180 C
Columns:	5' x $\frac{1}{8}$ " coiled glass with separate columns: 5% Dow-11 on 60/80 mesh Chromosorb W 2% QF-1 on 60/80 mesh Chromosorb W

The two columns were used separately for mutual confirmation of identifications. The QF-1 column was used for quantification and showed a sensitivity of at least 2.5 mm per picogram of *p,p'*-DDE in peak height on the chromatograms, with injection aliquots as low as 2 μ l. The biological material used in this study under the conditions of extraction and cleanup employed produced sufficiently low-noise chromatograms that peak heights of 5 mm could be unambiguously detected. Interlaboratory confirmation of a random sample of identifications was performed by personnel of the California State Department of Public Health, employing a MicroTek chromatograph on an SE-30 + QF-1 column.

Results and Discussion

In the early stages of the work, use of a more elaborate procedure allowing recovery of a more complete spectrum of chlorinated hydrocarbons showed indications of endrin, dieldrin, heptachlor epoxide and other compounds. Since *p,p'*-DDE was by far the most abundant and consistently detected material, our investigation was limited to a search for this compound. Tests of the above simplified procedure on samples "spiked" with known amounts of *p,p'*-DDE showed that recovery is virtually complete. Comparisons made early in the work of DDE content of fat-body tissue as compared with whole-body samples indicated that the former was generally above 1 ppm, while in the latter it was generally much less than .1 ppm. In whole-body analysis, moreover, a much more complicated extraction procedure was required, and chromatograms were not as low

in noise, making accurate detection very difficult. Hence, this study is limited to the analysis of fat-body tissue.

Although *p,p'*-DDE is not applied as a pesticide, it is one of the commonest metabolites of *p,p'*-DDT and a frequent storage form in animal tissues (8), as found, for example, by Dimond *et al.* (3, 4, 5) for salamanders, crayfish, and a variety of small mammals following DDT application in Maine forests. Its occurrence in the frogs in this study, therefore, is considered evidence of environmental DDT.

Geographic distribution of the occurrence of DDE in frog fat bodies is shown in detail in Tables 1-6. Table 7 summarizes comparatively the data of the others, and interpretation of the tables is best done by reference to the map of Fig. 1. Names of lakes, ponds, and streams are as labeled on standard quadrangles of the U. S. Geological Survey (11), as are altitudes, distances from the central valley, and geographic coordinates.

Latitudinal zonation is based on our discovery of notably high DDE concentrations in the area from the higher altitudes in Yosemite National Park to the Sonora Pass area. This area lies from about 37°40' north latitude to about 38°20'. Hence we have designated the zone between these limits as the Yosemite-Sonora zone. North of this we designate as the Northern Sierra Nevada. The area to the south being so much more extensive, we subdivide it at the 37°0' parallel into the Central and the Southern Sierra Nevada.

The greater amount of data accumulated from the Central Sierra Nevada permits us to compare values from the lower altitudes (below 5,000 feet) with those from higher altitudes on the western slope of the mountains, and both of these with concentrations across the crest, on the eastern face, as shown in Tables 3, 4, and 5.

The first generalization emerging from these data is that contamination of the range is general. In fact, of the several hundred animals we have examined from throughout the mountains, all contained at least some DDE. The 3.46 ppm average of the low-altitude Central Sierra is not significantly different from the 3.19 ppm high-altitude average (Tables 3 and 4), suggesting that concentrations are fairly uniform from low to high altitudes on the western face of the mountains. The abrupt drop to an average of 0.97 ppm (Table 5) just across the crest of the mountains is what would be expected from the hypothesis that the DDT residues are carried eastward from the central valley and that concentrations in the mountains are related to precipitation patterns.

The higher concentrations in the central and southern parts of the mountains (averages of 3.19 ppm, 3.46

ppm, and 2.07 ppm shown in Tables 3, 4, and 6, respectively) as compared to concentrations found in the northern parts of the mountains (average of 1.32, Table 1) are consistent with the greater agricultural area and more intense agricultural activity in the southern half of the central valley. The lower concentration in the Southern Sierra Nevada zone (2.07 ppm) as compared with the Central Sierra Nevada zone is probably attributable to the presence of the Great Western Divide to the west of the former. This Divide extends as a ridge parallel to the main crest and rises to over 13,000 feet. All but one sample (Smith-Failing Meadow) are from the main crest, and their lower DDE concentrations as compared with areas just north of the Great Western Divide probably reflect the protection from DDT of the main crest by fallout on the Divide. It might be predicted that were this Divide to be systematically sampled and tested, it would show DDE values for this part of the Southern Sierra Nevada as high as or higher than those found in the Central Sierra Nevada zone where this type of protection of the main crest is lacking.

Particularly noteworthy is the high concentration of DDE in the Yosemite-Sonora area, averaging 5.38 ppm as compared with the average of 3.19 ppm immediately to the south of this area or the average of 1.32 ppm immediately to the north thereof. It might be suspected that the two extraordinary values of single samples, 16.52 ppm from a pond near Mt. Clark and 30.83 ppm from the Koenig Lake area (Table 2) are mainly responsible for this high average, and that if these are regarded as suspect values, the average DDE concentration in this zone is not significantly higher than in adjacent zones. However, even if these two values were eliminated from Table 2, the mean value would be 4.27 ppm, and the standard error of the mean would be reduced to 0.444. Comparing this mean and standard error with the 3.19 ± 0.27 mean and standard error of the zone just to the south of the Yosemite-Sonora zone by a t-test for the significance of the difference between means shows a real difference at between the 95% and 98% confidence levels. Hence, the indication is that levels in this Yosemite-Sonora zone are significantly higher than elsewhere. There are, in fact, good reasons for expecting greater variability in sample values in this zone than elsewhere (see discussion below), so that these two high values, which are based on the same methodology and as carefully done as any other determinations in the investigation, probably represent elements in this variability and should be left in the table.

The higher average value in this region would not be expected for at least two reasons. For one thing, the average distance of sample sites from the central valley, 82 miles, is greater in this zone than in any of the other zones except the low-concentration zone east of the Sierra Nevada crest (Table 7). For another thing, this

zone lies east of the least agricultural part of the central valley due to the large part of this area occupied by the delta of the Sacramento and San Joaquin Rivers, an intermingling of swamps, channels, and small islands that occupy the greater part of the valley width in this region. Also, the urbanization immediately north and south of the delta area is much greater than elsewhere in the central valley, further reducing the intensity of agriculture in this part of the valley. It might be objected that the Yosemite-Sonora zone lies east of an enormous metropolitan area in which much DDT is employed. However, in such regions this material is applied largely within buildings, to gardens and patios, etc. by direct application rather than being applied, as in agricultural areas, in massive aerosol exposures by crop-dusting from airplanes.

Explanation of this unusual concentration seems to be provided by two reports (12) of the U. S. Forest Service. The first describes the application in 1953 of 11,024 lb of DDT in diesel oil to 11,140 acres of forest in the Tuolumne Meadows area of Yosemite National Park for control of the lodgepole needle miner. The second report describes the application in 1956 of 10,110 lb of DDT in diesel oil to 9,560 acres of timber in the Stanislaus National Forest for control of the Douglas-fir tussock moth. This acreage was distributed in several closely adjoining areas just to the west of Yosemite National Park and averaging about 10 miles north of the Mather area (Fig. 1). Forest sprayings have been unique in California; these two and one other north of the Sierra Nevada were the only ones found recorded. Hence, the unusual concentrations of DDE in the Yosemite-Sonora zone probably represent locally persistent residues of these 1953 and 1956 sprayings.

This interpretation is consistent with the few previous investigations on the persistence of DDT residues locally in the biota of a forest area. Dimond *et al.* (3, 4, 5), for example, found that following the spraying of forest areas in Maine at the rate of 1 lb/acre with DDT, the same rate as used in the 1953 and 1956 Sierra Nevada episodes, there was high concentration, especially of DDE, the first year following the forest application in the biota of the region (salamanders, crayfish, small mammals). A notable drop in concentration occurred the second year after application, but thereafter there was very little further decrease in concentration through a period of 9 years following application of DDT to the forest. These authors estimated that it would be well into the second decade following the forest treatment before there would be further significant drop in residue levels. Our interpretation of high levels in the frogs into the second decade following a forest application of DDT being due to this particular application is perfectly consistent with their findings.

Another feature worthy of note is found in one of the papers (5) of Dimond *et al.* This is the much greater

variability in DDT residue concentrations within populations following a single application of DDT than in populations repeatedly exposed or in populations subjected only to general residue drift through the environment. The high variability (2.96 - 16.52 ppm) in the population near Mt. Clark (Table 2) is probably a special consequence of the 1953 spraying episode (note position from geographic coordinates in Table 2 in relation to the Tuolumne Meadows, 1953 spraying). Similarly, the high variability (1.70 - 30.83 ppm) in the population of the Koenig Lake area (Table 2) is probably a consequence of the 1956 episode. This interpretation, at least, is consistent with the findings of the above cited authors and would explain the greater variability in levels found in the Yosemite-Sonora region as well as the greater average concentration present here as compared to that in other regions of the Sierra Nevada range.

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TABLES 1-7.—GEOGRAPHIC DISTRIBUTION OF THE OCCURRENCE OF *p,p'*-DDE IN FROG FAT BODIES (PARTS PER MILLION, WET WEIGHT). EACH *p,p'*-DDE VALUE FROM A SINGLE FROG EXCEPT IN TABLE 7

TABLE 1.—Northern Sierra Nevada, north of 38°20'

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Sutter Creek, between Sutter Creek and Volcano Amador Co.	9/18/66	17	38°26'	120° 4'	1,720	1.44 1.55 1.10 0.89 1.18 0.94 0.39
Pond near Hiram Peak Alpine County	9/16/67	68	38°29'	119°48'	9,000	1.11 0.51
Pond near Kinney Lakes Alpine Co.	9/16/67	70	38°34'	119°49'	8,500	1.52 0.95
Five Lakes area Nevada Co.	9/1/66	55	39°25'	120°33'	7,000	3.04
Snag Lake Sierra Co.	7/15/67	62	39°40'	120°38'	6,680	1.64 0.75 1.02 2.79 1.43 0.53 2.13
Average Values		54			6,580	1.32 ± 0.16 n = 19

TABLE 2.—Yosemite-Sonora area, $37^{\circ}40'$ - $38^{\circ}20'$

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Pond near Mt. Clark Mariposa Co.	7/2/66	72	$37^{\circ}42'$	$119^{\circ}25'$	9,880	16.52 9.94 2.96
Nydiver Lakes Madera Co.	8/29/68	89	$37^{\circ}42'$	$119^{\circ}10'$	10,160	2.00 2.50
Pond, Lyell Fork Merced R. Madera Co.	8/28/68	85	$37^{\circ}43'$	$119^{\circ}16'$	11,100	2.36 2.53
Pond, head Hutchings Cr. Madera Co.	8/27/68	84	$37^{\circ}44'$	$119^{\circ}17'$	10,960	7.75 6.40
Clark Lakes, Mono Co.	8/16/66	89	$37^{\circ}44'$	$119^{\circ}9'$	9,800	5.89
Upper Lyell Base Camp Tuolumne Co.	9/4/66	84	$37^{\circ}46'$	$119^{\circ}15'$	10,160	5.89 3.57
Lake near Mt. Hoffman Mariposa Co.	8/25/68	73	$37^{\circ}51'$	$119^{\circ}30'$	9,840	7.56 9.45 5.22
Gaylor Lakes Tuolumne Co.	10/1/66	90	$37^{\circ}55'$	$119^{\circ}16'$	10,400	1.31 1.85
Pond near Lundy Pass Mono Co.	8/26/68	90	$37^{\circ}59'$	$119^{\circ}18'$	10,400	3.00 2.00
Greenstone Lake Mono Co.	8/26/68	90	$37^{\circ}59'$	$119^{\circ}17'$	10,150	4.30
Pond near Gianelli Tuolumne Co.	7/15/67	60	$38^{\circ}12'$	$119^{\circ}52'$	8,680	1.45 3.56
Upper Relief Valley Tuolumne Co.	8/3/66	63	$38^{\circ}14'$	$119^{\circ}47'$	8,800	5.45 9.47 4.06
Koenig Lake & vicinity Mono Co.	7/10/66	72	$38^{\circ}17'$	$119^{\circ}38'$	9,560	30.83 5.91 5.05 2.08 1.70 6.80 3.62 1.58 1.80 1.87
Average Values		82			9,992	5.38 ± 0.93 <i>n</i> = 35

TABLE 3.—Central Sierra Nevada, $37^{\circ}0'$ - $37^{\circ}40'$, western slope, 5,000 ft. to crest

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Stevenson Creek, Fresno Co.	9/2/66	41	$37^{\circ}6'$	$119^{\circ}15'$	5,420	3.79 2.93
Unnamed lake, McGee L area, off Evolution Valley Fresno Co.	8/28/67	76	$37^{\circ}9'$	$118^{\circ}43'$	10,900	2.49 2.08 5.36 2.01 2.24
Red Lake Fresno Co.	7/3/67	58	$37^{\circ}11'$	$119^{\circ}5'$	9,000	2.41 3.54
Goddard Canyon Fresno Co.	8/16/67	74	$37^{\circ}12'$	$118^{\circ}47'$	8,500	1.33 0.70
Darwin Canyon Fresno Co.	7/18/68	74	$37^{\circ}12'$	$118^{\circ}41'$	11,680	1.45 2.65
Dowville, Huntington L. Fresno Co.	8/14/67	55	$37^{\circ}14'$	$119^{\circ}14'$	6,959	4.42 2.75
Humphries Basin Fresno Co.	7/4/68	87	$37^{\circ}15'$	$118^{\circ}42'$	11,200	1.08 1.11
Dutch Lake Fresno Co.	7/4/67	71	$37^{\circ}15'$	$119^{\circ}0'$	9,200	0.42 0.39
Pond, head of Line Cr. Fresno Co.	8/15/66	62	$37^{\circ}17'$	$119^{\circ}11'$	9,000	2.11 3.31
Rosebud Lake Fresno Co.	7/16/68	82	$37^{\circ}18'$	$118^{\circ}54'$	10,800	3.86 1.76

TABLE 3.—*Central Sierra Nevada, 37°0'-37°40', western slope, 5,000 ft. to crest—Continued*

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Pond NE of Kaiser Pk. Fresno Co.	8/14/66	63	37°18'	119°10'	9,800	9.07 5.81
Kaiser Pass Meadow Fresno Co.	7/12/67	68	37°18'	119° 6'	9,115	2.28 3.28
Bear Lakes Basin Fresno Co.	7/14/68	90	37°19'	118°48'	11,425	1.94 1.63
Lake near Infant Buttes Fresno Co.	7/20/68	83	37°20'	118°55'	10,400	2.68 3.47
Lake Italy Fresno Co.	7/11/68	92	37°22'	118°48'	11,154	4.22 5.14
Treasure Lakes Inyo Co.	8/22/68	97	37°23'	118°46'	11,160	4.41 5.14
Onion Springs Mdw. Fresno Co.	8/13/67	79	37°24'	119° 4'	7,840	4.35 3.88
Hedrick Meadow Fresno Co.	8/17/68	81	37°26'	119° 4'	9,040	1.30
Snow Lakes Fresno Co.	9/1/67	97	37°26'	118°47'	11,000	5.18 2.95 4.78 3.34
Devil's Bathtub Fresno Co.	8/27/67	85	37°27'	119° 0'	10,160	8.36
Graveyard Meadow Fresno Co.	8/30/66	87	37°27'	118°58'	10,000	3.03
Marilyn Lakes basin Fresno Co.	8/30/66	88	37°28'	118°59'	9,960	6.21 1.43
Duck Lake Fresno Co.	7/27/68	92	37°33'	118°58'	10,427	2.16 1.43
Average Values		77			9,745	3.19 ± 0.27 n = 48

TABLE 4.—*Central Sierra Nevada, 37°0' - 37°40', western face below 5,000 feet*

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Big Creek, tributary So. Fork Kings River near Bretz Mill Fresno Co.	9/11/66	36	37° 2'	119°15'	3,240	2.89 4.35 2.52 4.19 3.17 2.03 3.69 2.41 3.80 3.61
Sycamore Creek Fresno Co.	9/11/66	32	37° 2'	119°19'	4,200	4.59 4.32
Average Values		34			3,720	3.46 ± 0.25 n = 12

TABLE 5.—*Central Sierra Nevada, 37°0'-37°40', east of main crest.*

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Bishop Creek canyon, near Long Lake Inyo Co.	10/14/67	83	37° 9'	118°27'	10,700	0.69 1.70 1.00 1.97
Chalfant L., Inyo Co.	7/10/68	94	37°21'	118°46'	11,200	0.06
Little Lakes Valley Mono Co.	8/20/67 8/1/66	100	37°26'	118°45'	10,400	1.12 0.77
Sherwin L., Mono Co.	8/9/68	96	37°37'	118°57'	8,560	0.73
Pond at Pumice Flat Madera Co.	7/3/66	89	37°39'	119° 5'	7,680	0.70
Average Values		92			9,708	0.97 ± 0.19 n = 9

TABLE 6.—*Southern Sierra Nevada, 36°0' - 37°0'*

LOCATION & COUNTY	DATE	MILES TO VALLEY	NORTH LATITUDE	WEST LONGITUDE	FEET ALTITUDE	PPM <i>p,p'</i> -DDE
Smith-Failing Mdw. Tulare Co.	9/9/67	28	36° 9'	118°33'	7,440	1.97 2.32
Lower South Fork Lake Inyo Co.	7/24/68	60	36°28'	118°13'	10,990	1.90
Cottonwood Lakes Inyo Co.	7/23/68	59	36°29'	118°13'	11,120	0.73 2.23
High Lake, Inyo Co.	7/22/68	58	36°29'	118°14'	11,475	3.18
Mdw., Upper Rock Creek Tulare Co.	7/23/68	56	36°30'	118°16'	10,650	2.30 1.50
Pond at Crabtree L. Tulare Co.	9/18/68	55	36°33'	118°19'	11,500	2.10 1.50
Hitchcock Lakes Tulare Co.	9/19/68	54	36°34'	118°19'	11,750	2.77 1.84
Wright Lakes Tulare Co.	9/17/68	54	36°37'	118°22'	11,440	1.72
Pond at Tyndall Creek Tulare Co.	9/17/68	56	36°40'	118°23'	12,000	2.01 4.37
Pond, Vidette Canyon Tulare Co.	9/16/68	54	36°44'	118°24'	10,820	0.48 3.93
Kearsarge Lakes Fresno Co.	9/15/68	61	36°46'	118°24'	10,640	1.00 1.50
Average Values		54			10,893	2.07 ± 0.26 n = 19

TABLE 7.—*Summary of the occurrence of *p,p'*-DDE in fat bodies of frogs from the Sierra Nevada Mountains (parts per million, wet weight)*

SIERRA NEVADA MOUNTAINS	AVG. FEET ALTITUDE	NO. OF LOCALITIES	Avg. Miles to Valley	No. of Samples	AVERAGE PPM DDE ± S.E.
Northern (North from 38°20')	6,580	5	54	19	1.32 ± 0.16
Yosemite-Sonora (37°40'-38°20')	9,992	13	82	35	5.38 ± 0.93
Central (37°0'-37°40') West face to 5,000 feet	3,720	2	34	12	3.46 ± 0.25
West face over 5,000 feet	9,745	23	77	48	3.19 ± 0.27
East of crest	9,708	5	92	9	0.97 ± 0.19
Southern (36°0'-37°0')	10,893	11	54	19	2.07 ± 0.26